Indian J. Phys. **75B** (3), 163–165 (2001)

I J P B
— an international journal

Design and development of cassegrain antenna with wide and narrow coverage

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Abstract : A single antenna that can realize the performance of contradictory requirements of wide and narrow coverage over a band of frequency is to be designed. A novel technique of axial defocused cassegrain antenna system is presented in this paper with wide and narrow beam coverage Antenna fabrication and testing is presented A comparison of simulated and tested results is also presented

Keywords : Cassegrain antenna.

PACS No. . 84.40 Ba

1. Introduction

In order to maintain RF link between an airborne vehicle and the ground system, a configuration consisting of two antennas, one for wide beam coverage and another for narrow beam coverage are generally used to take care of initial launch dispersion. The link is maintained by wide beam antenna till the target attains certain height and is switched over to narrow beam antenna. Alignment of the two antennas for optimum performance becomes difficult. In order to eliminate complex networking and loss of information during the switching time from one antenna to another, and also to minimize the alignment problems and weight constraints, a most efficient system had to be established. Feasibility of realizing this performance of contradictory requirements of wide and narrow coverage, high gain and low VSWR over the band of frequencies with a single antenna is studied extensively. As no standard antenna can provide this performance the technique of defocusing axial feed of cassegrain antenna is considered to meet the requirement. Cassegrain system has several advantages like elimination of long transmission lines, more flexibility in design of primary feeds, low spillover past the subreflector *etc.*, hence the Cassegrain system is considered for the design.

2. Theory

The classical cassegrain geometry employs a parabolic contour for the maindish and a hyperbolic contour for subdish. One of the two foci of the hyperbola is the real focal point of the system, and is located at the center of the feed. The other is a virtual focal point, which is located at the focus of the parabola. As a result, all parts of the wave originating at the real focal point, and then reflected from both the surfaces travel equal distance to a plane in front of the antenna. In axial defocusing, the reflector will be iluminated, with a feed positioned away or towards from the reflector focal point. This feed displacement introduces phase aberration which results in pattern distortion in terms of gain loss, side lobe level degradation *etc.* Deep nulls that were present in a conventional radiation pattern are filled up in proportion with the amount of defocusing and aperture taper. In order to simplify the design analysis equivalent paraboloid principle is used. Detailed analysis is reported in [1–15] for axially defocused pointsource feed using numerical integration and physical optics.

3. Design

A. Feed design :

The most important part of the antenna is its feed. Conical corrugated horn in chosen for the design as it gives optimum and efficient performance in terms of gain, equal beam widths in both the planes, low cross polarization *etc.* The input electrical parameters, which determine the performance of the corrugated horn, are as follow [6–7] :

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(i) Radiation patterns : Principal plane patterns, pattern symmetry, beamwidths.

(ii) Frequency characteristics : Frequency of operation, bandwidth.

(iii) Efficiency as feed : Total aperture illumination, spillover, gain, input impedance and VSWR.

(iv) Mechanical : External diameter, length.

From above mentioned inputs it has been identified four output parameters. They are (a) the aperture diameter and flare angle which principally determine the copolar beam width; (b) the corrugations, which determine the pattern symmetry and cross polar characteristics; (c) the flair section between the throat and the aperture which determines the position of the phase center and the generation of any higher order modes along the horn; (d) the throat region which determines both the impedance match into the section of the waveguide behind the horn and the mode conversion level at the throat.

B Main and sub-reflector antenna design :

The diameter of the main reflector is selected to give required gain and beamwidth of the total integrated antenna. The sub-reflector diameter and the conical corrugated feed diameter are selected based on minimum blockage criteria. Uniform aperture distribution is selected in order to give maximum efficiency. The diameter of the main dish is 13λ and sub-reflector is 3.02λ. The focal length of the reflector is 4.55λ. Half illumination angle of parabolic reflector is 71.07 deg. and that of hyperboloid is 23 deg.

4. Fabrication, integration and testing

This is the most difficult part of the antenna design. High precession machining is needed in order to get good surface

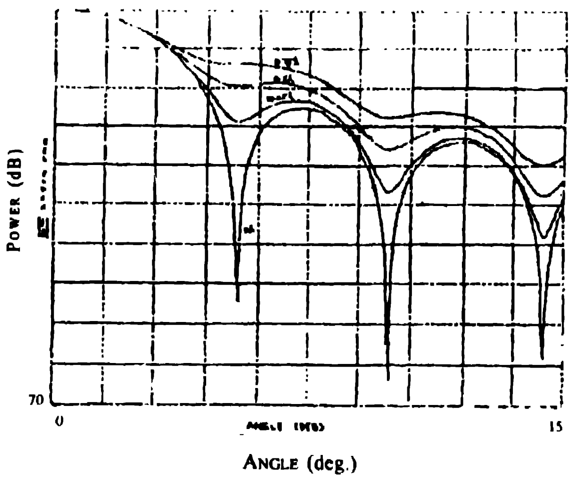

Figure 1. Variable axial defocusing of parabolic reflector.

finish. CNC turning is used for getting above precession and mechanical tolerances. Aluminum alloy is used for fabrication of the antenna for its lightweight, good mechanical and electrical properties. Silver coating or conductive chromotization is used to improve the reflective properties of the antenna. After complete fabrication all the components are integrated to form the complete antenna.

The effect of axial feed desplacement on sidelobe level degradation for various displacements has been simulated and is given in Figure 1. Also gain degradation for feed displacements towards and away from the reflector is simulated.

Feed optimization : the conical corrugated feed is excited by rectangular wave guide and its depth is adjusted experimentally in order to cover the required frequency range for the same illumination angle and gain. The feed pattern after optimization is shown in Figure 2. Similar patterns were obtained for different frequencies.

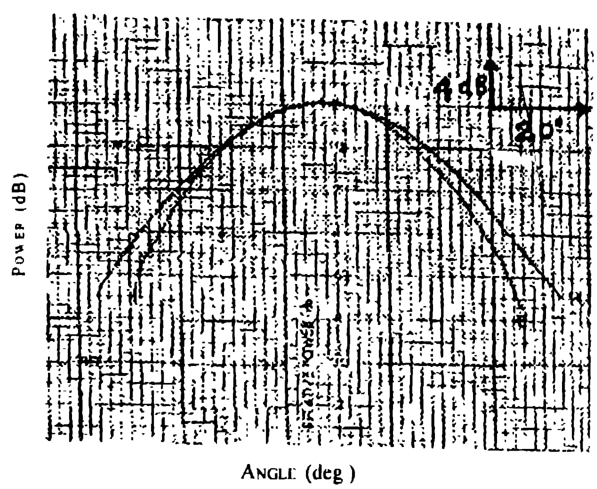

Figure 2. Radiation pattern of the feed.

Fixing the position of the feed and sub reflector

Necessary fixtures for feed and total integrated antenna are fabricated. They are required for mounting on the positioner. VSWR measurement for the feed and complete integrated antenna is carried out on network analyzer for the total band of operation.

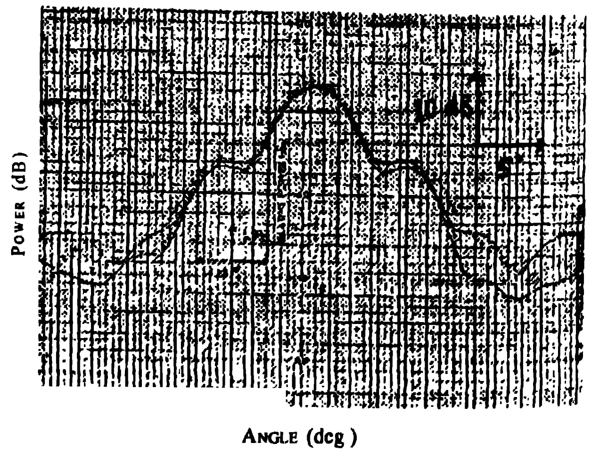

Figure 3. Radiation pattern of integrated antenna.

After detailed experimental analysis, the optimum feed position is fixed in defocused condition is found to be 1.5λ from the vertex of the main dish. The corresponding sub-reflector position is 4.33λ from the vertex of the main dish. The gain of the antenna at the given band of frequency is found to be 26dB. The radiation pattern of the complete integrated antenna is shown in Figure 3. Both E-plane and H-plane patterns along with the inter cardinal planes are shown in the figure. A complete integrated antenna after testing is shown in Figure 4.

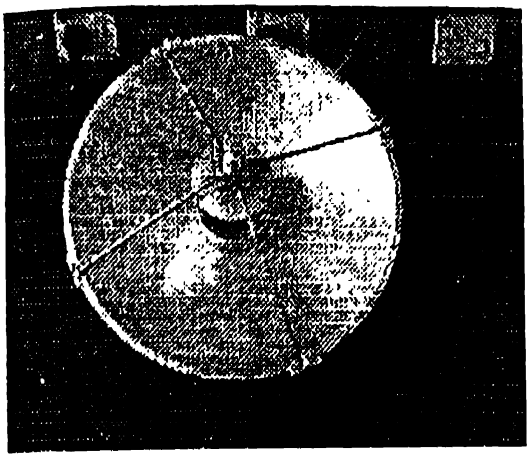

Figure 4. Complete integrated antenna

5 Conclusions

From the simulated results (Figure 1) and the tests carried out at compact range, it can be found that 3db beamwidths are matching closely. The required coverage of 16° is obtained 12dB down the maximum gain. This is 2dB down that of simulated pattern. The coverage obtained is well in conformation with the simulated patterns considering the tolerances.

Acknowledgments

The authors wish to express their sincere thanks and appreciation's to Shri K V S S Prasada Rao, Director, RCI, A K Kapoor, Project Director and Chattopadhyay, Deputy Project Director for their encouragement and help. They are indebted to R Das, Technology Director, DEM for his constant support and guidance. V Dharmanandam and Muthu Azahgam need special mention for testing the antenna. They also thankful to Dr. S R Ramaswamy and Mrs. S Sinha for their valuable suggestions in writing the paper.

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